light is sufficiently great, the sense of the displacement can be changed. The effect of the second lamp on the energy of the magnetic levels disappears if the beam is unpolarized.

Barrat and Cohen-Tannoudji[11] also suggested a model in which the optical pumping process couples a portion of the Zeeman energy of the excited state to the ground-state Zeeman levels. This effect might be expected to be important in the case of optical pumping in helium because the low absorption cell pressure permits the pumping cycle to take place without a reorientation of the atomic spins while an atom is in the P state. This effect should depend on some way on the magnetic field in that the Zeeman energy separation of the excited states is increasing with magnetic field. To test this possibility the experiment of Fig. 3 was repeated in magnetic fields from 26 mG to 1.4 G, a range of almost 50 to 1. There was no noticeable change in the shift. This lack of dependence on the field intensity also minimizes the possibility that the shifts are associated with the presence of polarized free electrons and/or helium ions.

ACKNOWLEDGMENTS

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Hyperfine Structure of Cs^{134m}†

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The nuclear magnetic moment of Cs^{134m} has been measured independently of the electron-nucleus interaction energy ΔW by observing the separation of components of the doublet $(17/2, -13/2) \leftrightarrow (15/2, -15/2)$ and $(17/2, -15/2) \leftrightarrow (15/2, -13/2)$. The frequency difference $\delta\nu = 2g_I\mu_0 H$ is observed in the vicinity of a frequency minimum for each transition. The value obtained for μ_I is 1.0964(2) nm corrected for atomic diamagnetism, giving a hfs anomaly between Cs^{133} and Cs^{134m} of $-0.0139(2)$. The direct transition near zero field has been measured to give $\Delta\nu = 3\,684\,578\,640(175)$ cps.

INTRODUCTION

It has been shown[1] that s, and to a smaller extent p electrons, penetrate the finite volume occupied by the nucleus and, therefore, the interaction between the nucleus and the electrons will depend to a small extent upon the spatial distribution of nuclear charge and magnetization inside the nuclear volume.

The Goudsmit-Fermi-Segrè formula,[2–4]

$$\Delta W = \frac{16}{3}\pi\frac{\mu_I}{I}(2I+1)[\psi(0)]^2, \tag{1}$$

which gives a good approximate value of the interaction energy between an electron and the nucleus, considers the nucleus as a point magnetic dipole. The greatest inaccuracy in this formula is due to the uncertainty in the electron distribution. For two isotopes, however, the electron distributions would be nearly identical and one would expect that the relationship

$$\frac{\Delta\nu_1}{\Delta\nu_2}\frac{\mu_1}{\mu_1}\frac{I_1}{I_2}\frac{(2I_2+1)}{(2I_1+1)} = 1 \tag{2}$$

should hold to a high degree of precision.

If now we consider the differing distribution of nucleons in the two isotopic nuclei and the interaction with the penetrating electron, we must modify Eq. (2) slightly by the term ${}_1\Delta_2$ referred to as the hyperfine structure anomaly, defined by the relationship

$$1 + {}_1\Delta_2 = \frac{\Delta\nu_1\mu_2 I_1(2I_2+1)}{\Delta\nu_2\mu_1 I_2(2I_1+1)}. \tag{3}$$

The hyperfine structure anomaly was first considered by Bohr and Weisskopf, who found that ${}_1\Delta_2$ can be a sensitive function of the nuclear model describing the distribution of nucleon spin and magnetization associated with orbital motion. Measurements of ${}_1\Delta_2$ may therefore provide one test for nuclear models. Most anomalies heretofore reported have been less than 0.01.

The principal objective of this research was the

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[1] A. Bohr and V. Weisskopf, Phys. Rev. **77**, 94 (1950). See for example, H. Kopfermann, *Nuclear Moments* (Academic Press Inc., New York, 1958), p. 123ff.

[2] S. Goudsmit, Phys. Rev. **43**, 636 (1933).

[3] E. Fermi and E. Segrè, Z. Physik **60**, 320 (1930).

[4] E. Fermi and E. Segrè, Z. Physik **82**, 729 (1933).

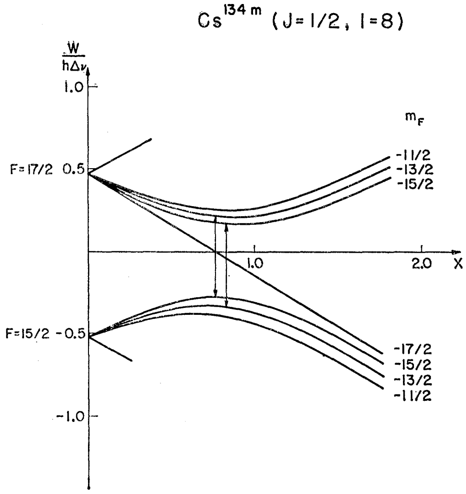

FIG. 1. Energy-level diagram for some of the magnetic substates of Cs^{134m} as a function of magnetic field. The field is plotted in units $X=(g_J-g_I)\mu_0H/h\Delta\nu$, energy in units of $W/h\Delta\nu$.

determination of the hyperfine structure anomaly between the isomer Cs^{134m} and the stable Cs^{133}.

The quantity $\Delta\nu$ can be measured quite readily by atomic beam resonance methods with extremely high precision. Because of the low isotopic concentration of Cs^{134m} in the presence of the stable Cs^{133}, μ_{134m} cannot be measured by nuclear resonance, the method customarily used for precision determination of μ_I. It is possible, however, to measure this quantity by atomic beam methods with adequate precision. Examination of the modified Breit-Rabi equation[5] shows that the transitions in which $\Delta_F=\pm1$ and $\Delta m_F=\pm1$ form a close doublet for which the splitting is exactly 2 $g_I\mu_0H$, where $g_I\equiv-\mu_I/I$ and μ_I is given in Bohr magnetons. There is a region in which one pair of these transitions passes through a frequency minimum as shown in Fig. 1. These transitions can be observed in a "flop-in" type of magnetic resonance atomic beam apparatus. In this vicinity the dependence of frequency upon field is greatly reduced so that control of the C field adequate for observing doublet frequencies to about 1 part in 10^8 is quite feasible. Figure 2 indicates the variation of frequency with field and the corresponding frequency of the Cs^{133} field-dependent line used for field calibration. Since ${}_1\Delta_2$ was expected to be of the order of 0.01, it was our objective to measure g_I to better than 1 part in 10^3. The doublet splitting is of the order of 200 kc/sec at a frequency near 2000 Mc/sec so that one must measure the transition frequencies to an accuracy of ±200 cps or less, or a precision of 1 part in 10^7 or better. It is clear that extremely narrow lines and precise frequency control are necessary.

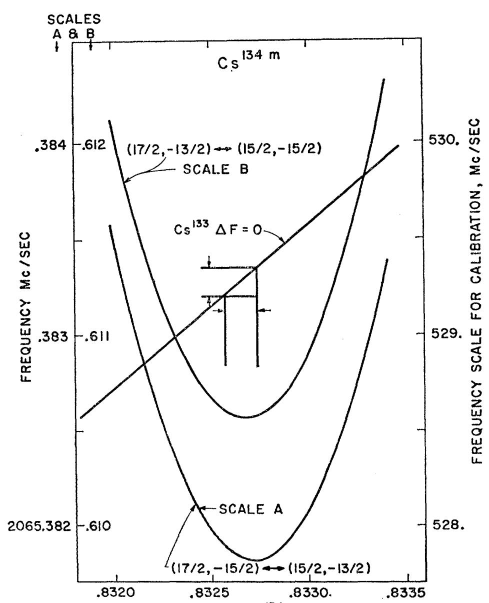

FIG. 2. Curves A and B show the field dependence of the two transitions, the difference of which gives g_I from the relation $\nu_B-\nu_A=2g_I\mu_0H$. The straight line represents the field-dependent transition $(3,-3)\leftrightarrow(3,-2)$ used to determine the field. The solid lines between the arrows indicate the extreme limits of error in determination of the frequency of this transition.

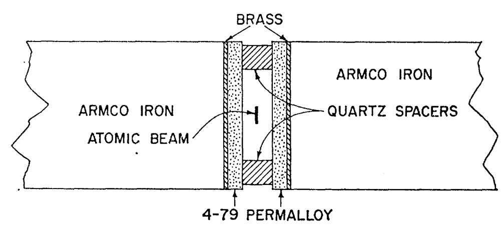

FIG. 3. Schematic arrangement of a cross section of the C field perpendicular to the beam axis.

APPARATUS

The apparatus[6] used in this experiment was a modification of the one used for the Cs^{134m} spin determination which was in essence similar to that described by Goodman and Wexler.[7] The principal modifications were in the C field and the rf system.

C Field. The vacuum chamber was elongated to permit a new C field 12 in. long to replace the original one of 3 in. The magnet gap spacing was approximately 0.4 in. and 2 in. high. The auxiliary gaps in series with the man gap suggested by Purcell[8] were incorporated in the design (see Fig. 3). The pole faces were made of 4-79 molybdenum Permalloy, approximately $\frac{3}{8}$-in. thick, ground and spaced with quartz blocks to give a gap parallel to within about 0.0001 in. In the vicinity of 1000 G the extreme variations of field over the beam path was about 0.1 G.

[5] R. Kusch, S. Millman, and I. I. Rabi, Phys. Rev. **57**, 765 (1940), added the g_I term to the formula first shown by G. Breit and I. I. Rabi, *ibid.* **38**, 2082 (1931).
[6] V. W. Cohen, D. A. Gilbert, Phys. Rev. **95**, 569 (1954).
[7] L. Goodman and S. Wexler, Phys. Rev. **95**, 570 (1954).
[8] L. S. Goodman, Rev. Sci. Instr. **31**, 1351 (1960).

In order to observe an undistorted resonance pattern of the "Ramsey" separated oscillatory fields type it is necessary that the resonant frequency at the two "Ramsey" loops be nearly equal to the mean frequency of the atoms over their path between the loops. Even in the region of the frequency minimum care must be taken to make the variation of the C field over the entire transition region small compared to width of the central peak of the pattern. Since any portion of the C field which departs from the value for the minimum tends to *raise* the average frequency, one accumulates an error which is always on the *high-frequency* side of the true minimum frequency. For evaluation of the g_I term, by taking the difference between the two frequencies, this error should cancel out.

Loop system. The rf loops shown schematically in Fig. 4 are essentially shorted terminations of a resonant

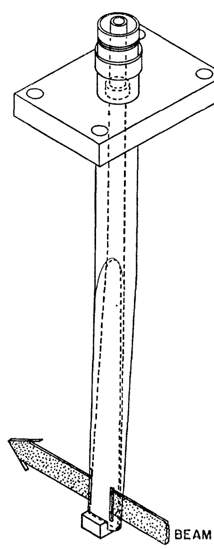

FIG. 4. Sketch of the rf loop furnishing the oscillating magnetic field perpendicular to the C field. The loop, shorted at the bottom, forms a gradual transition from circular to an elongated coaxial line.

coaxial line. The line has a "trombone" stretcher to adjust the total length between the ends. (See Fig. 5.) The approach to each end of the line is tapered from a circular cross section to an elongated shape with the center conductor fanning out to a length of $\frac{3}{4}$ in. and thickness of about 0.04 in. The beam runs parallel to the $\frac{3}{4}$-in dimension close to the termination and experiences an oscillating magnetic field parallel to its motion. This type of loop can be used to induce transition $\Delta m = \pm 1$ as discussed above and also the $\Delta F = \pm 1$ transitions which are field independent near zero field, from which μ_I can be measured.

Five similar loops were installed in the C-field region as shown in Fig. 6. By choosing any combination of two of the five rf loops it was possible to vary the spacing of the "Ramsey" pattern. Any single loop can be used to produce a field-dependent resonance for calibration purposes. By examining a field-dependent resonance in

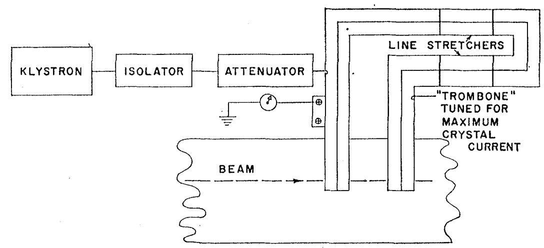

FIG. 5. Block diagram of the rf supply and resonant line system.

each loop in turn, one could determine roughly the variation of field over the C-field region.

The power level in the resonant loop line was monitored with a coaxial bidirectional coupler incorporating two rectifier crystals. The crystal current, measured with an electronic millimicroameter, gave an indication for the correct position of the tuning "trombone." The Q of the line was about 1000 and the power input required was of the order of a few milliwatts.

Rf *System.* The rf generating system was designed with the following objectives:

(1.) To have a long term stability determined by the reference crystal.

(2.) To be able to vary the frequency by a few cps at the operating frequency near 2065 Mc/sec.

(3.) To have the output signal with a residual frequency modulation of not over 1 part in 10^8.

(4.) To be able to vary the power level in the loop to the optimum for maximum "flop" intensity.

The general arrangement is shown in Fig. 7.

The reference crystal oscillator operating at 100 kc/sec was monitored against *WWV*, and after the data was obtained, checked against transmission from station A5XA at Ft. Monmouth, New Jersey at $133\frac{1}{3}$ kc/sec and was uncertain by about 3 parts in 10^8. The crystal signal was multiplied to 1, 10, and 100 Mc/sec by a General Radio No. 1112A standard frequency multiplier.[9] The 100 Mc/sec, producing a fifth harmonic in a crystal multiplier, was used to phase-lock the Gertsch FM4 oscillator at 510 Mc/sec. This output in

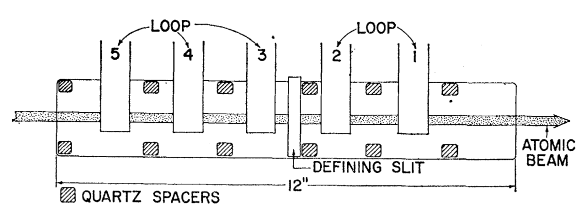

FIG. 6. Vertical section of the C-field gap showing the quartz pole-face spacers, the rf loops, and the defining slit. The loops could be used either singly or any pair could be coupled to produce a "Ramsey" pattern. The combination of loops 2 and 3 could be used to produce a broad line for moderate precision and loops 1 and 5 a narrower line for highest precision.

[9] The authors are greatly indebted to Frank Lewis of the General Radio Company for the loan of one of these instruments during the early phase of this experiment.

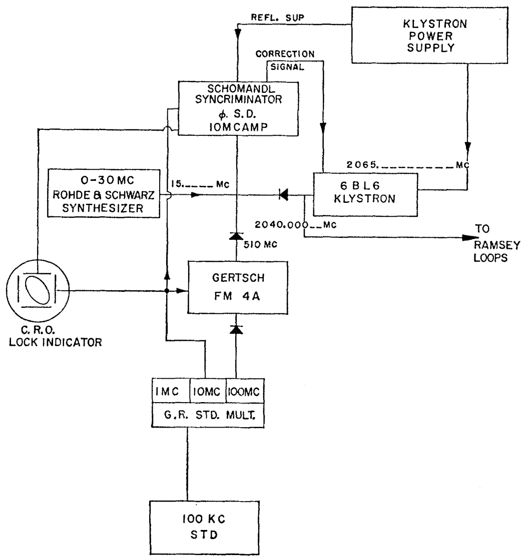

FIG. 7. A block diagram of the rf synthesizing system. The basic stability of about 1 part in 10^8 was furnished by the 100-Mc/sec standard while variable increments as small as 1 cps could be introduced by the Rohde and Schwartz synthesizer.

turn, through a crystal multiplier produced 2040 Mc/sec which when mixed with a variable frequency near 15.384 . . . generated by the Rohde and Schwartz frequency synthesizer gave a reference frequency which could be varied by an increment as small as one cps. This reference signal when beat against the klystron (6BL6) output gave a 10-Mc/sec signal which, operating through the Schomandl FDS3 "syncriminator" (a 10-Mc/sec amplifier and phase detector) would phase lock the klystron to exactly 10 Mc/sec above the reference signal. The 10-Mc/sec intermediate frequency reference used in both the Gertsch FM4 and the syncriminator was derived from the General Radio multiplier.

The final klystron output was tested for residual frequency modulation with a Stalo Tester No. 392, made by the Airborne Instrument Company.[10] After modifying the Gertsch FM4 by operating the tube heaters with dc, the extreme limits of frequency modulation over a 1/100-sec period was about one part in 10^8. The output of the klystron was passed through a ferrite isolator and then a variable attenuator before being coupled to the tuned line.

DETECTION

The beam intensity was measured by allowing the focused beam to pass through a detector slit and then deposit on a soot-coated square of brass 1 in. on edge. The brass square could be removed from the apparatus through a vacuum lock and its radioactivity measured in a continuous-flow Geiger counter.

PROCEDURE

The beam material, in the form of Cs metal enclosed in a quartz capsule, was irradiated for 4 h in the Brookhaven reactor at a flux of about 8×10^{12} (n/sec)/cm^2. The oven was loaded with the active Cs capsule which was crushed in an atmosphere of argon.

A series of runs was made to determine $\Delta\nu$. The C field was adjusted to as low a value as possible and still avoid "Majorana" flop, i.e., transitions induced by residual field so low that the atomic resonant frequency is comparable to the rate of rotation of the magnetic field as observed in a coordinate system moving with the atom between the A and B fields. The value of C field chosen was that which produced a Cs^{133}, $\Delta F=0$ resonance at 150 kc/sec or approximately 0.29 G. Since the central maximum is nearly field independent, it was possible to insure the identification of it by observing it under varying field conditions.

For the observation of the Cs^{134m} doublet the C field was homogenized by subjecting it to decreasing minor hysteresis loops and then set at a value to give the Cs^{133}, $\Delta F=0$ resonance at about 529.26 Mc/sec, computed to give the correct value for the frequency minimum of Cs^{134m} (see Fig. 2). The 529-Mc/sec signal was produced by a General Radio Unit Oscillator No. 1209A and could be maintained to about ±1 part in 10^5 during a run. The frequency was measured with a frequency meter, U.S.A. Signal Corps. type T/S 175.

For the determination of g_I a resonance curve such as Fig. 8 was taken using rf loops No. 3 and No. 4. For the final determination of g_I using loops No. 1 and No. 5 only the central peaks of each component of the doublet were examined in alternate turns taking one set of points for each. This tended to average residual fluctuations in the reference crystal which amounted to just under 1 part in 10^8 with a period of about 30 min. A composite plot of three passes over each line is shown in Fig. 9.

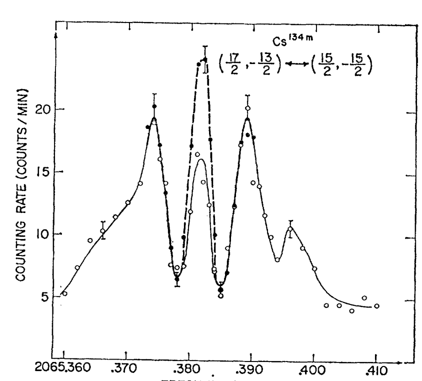

FIG. 8. "Ramsey" type resonance of the $(17/2, -13/2)\leftrightarrow(15/2, -15/2)$ transition. The solid curve was observed with excessive rf power. The broken line was taken near optimum rf power level.

[10] The authors are greatly indebted to the Airborne Instrument Company for the loan of one of these instruments during the early phase of this experiment.

RESULTS

$\Delta\nu$ determination. For the determination of the hfs splitting at zero field several experimental curves were taken of the "field-independent" $\Delta F=\pm 1$, $m_F=\pm 1/2 \leftrightarrow m_F=\mp 1/2$ lines. Through the points of each set a smooth curve was drawn and the center determined by taking the average of two points of equal intensity. The curves appeared to be quite symmetrical and gave an average value of 3 684 578 840 cps. The scatter of the measured center points nearly all lie well within the limit of ± 40 cps which we assign as a maximum limit of error due to statistics of counting and accidental sources. The uncertainty due to the frequency of the reference quartz crystal oscillator was about ± 100 cps. Some error could be attributed to a slight phase shift between the ends of the resonant line furnishing the oscillatory fields. Measurements made with the same rf resonant line on the Rb^{85}, $\Delta_F=\pm 1$ doublet at the frequency minimum were compared with the value calculated from the precisely measured value of $\Delta\nu$ for Rb^{85} and show that the phase shift error might have been as large as ± 30 cps.

The observed transition is subject to a correction due to the small term in the frequency expression which is quadratic in magnetic field. There is some uncertainty in the value of this term because of the variation in field over this region and fluctuation in time. This correction amounts to -200 cps. Numerous measurements made subsequently with Rb^{85} show that the error in this correction is probably less than ± 5 cps. Considering corrections and errors the value of $\Delta\nu$ is evaluated as 3 684 578 640 ± 175 cps.

Measurement of g_I and ${}_{133}\Delta_{134m}$. Figure 9 shows a composite plot of 3 passes over the central resonance peak for both components of the doublet. For each transition two such groups of curves were taken and analyzed individually as in the very low-field transition. The self-consistency of centers of the curves for the two transitions was perhaps better than the true accuracy. A conservative estimate of the maximum error is about 25 cps. The mean value of the doublet separation as measured is 228 712 ± 25 cps. For the determination of g_I the primary measurement is the difference in frequency $\delta\nu$ between the two transitions of the doublet. The systematic errors due to phase shift in the loop, variations in the value of the C field, and errors of the crystal standard would each drop out in taking the frequency difference. $g_{I_{134m}}$ is determined from the relationship

$$g_{I_{134m}}=\frac{\delta\nu}{2}\frac{(g_J-g_{I_{133}})}{X_{133}\Delta\nu_{133}}, \tag{4}$$

where X is defined as $(g_J-g_I)\mu_0 H/\Delta\nu$.

In computing the value of $g_{I_{134m}}$, we take the following

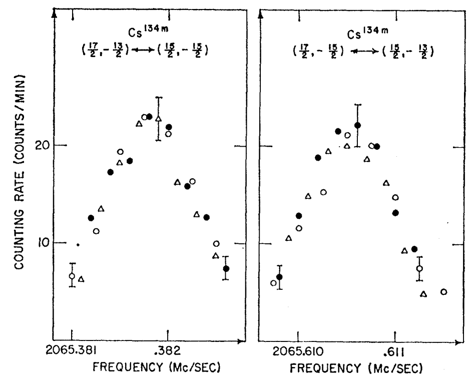

FIG. 9. Experimental curves of the central resonance of the two lines used to determine g_I.

constants for Cs^{133}:

$\Delta\nu=9\ 192\ 632$ Mc/sec,[11]

$I=7/2$,[12]

$\mu_{133}=2.5789(3)$,[13] with diamagnetic correction,

$g_J=2.002577$.[14]

From the above data[14a] we compute μ_{134} to be 1.0964 ± 0.0002 nm and ${}_{133}\Delta_{134m}=-0.0139\pm 0.0002$.[15]

INTERPRETATION IN TERMS OF SIMPLE NUCLEAR MODELS

It is interesting to see if the moment of Cs^{134m} can be understood using simple nuclear models. We have applied the single-particle model (S.P.M.), an empirical model based on quenched nucleon spins and the collective model[16,17] to this nucleus. As pointed out by Cohen and Gilbert,[6] there are two possible single-particle configurations able to explain a spin of 8 in Cs^{134m}, $d_{5/2}(p)\,h_{11/2}^{-1}(n)$ or $g_{7/2}(p)\,h_{11/2}^{-1}(n)$, which we shall call configuration D and G, respectively, and which are used as starting points for the empirical model as well as the collective model. Since the calculations are straightforward they will not be described in detail. The essential assumption involved for the S.P.M. calculation is that the angular momenta of the odd neutron and odd proton couple in pure j-j fashion.

[11] W. Markowitz, R. Glenn Hall, L. Essen, and J. V. L. Parry, Phys. Rev. Letters **1**, 105 (1958).
[12] V. W. Cohen, Phys. Rev. **46**, 713 (1934).
[13] H. E. Walchli, thesis, 1954, University of Tennessee (unpublished); also Oak Ridge National Laboratory Report ORNL-1775 (unpublished).
[14] P. Kusch and H. Taub, Phys. Rev. **75**, 416 (1949).
[14a] *Note added in proof.* Using the value $\mu_{133}=2.563201$ obtained from Dean Edmunds Ph.D. thesis, MIT, 1958, the value of Δ becomes $-0.0135(2)$.
[15] The value reported by J. W. Cohen and J. Schwartz, Bull. Am. Phys. Soc. **5**, 273 (1960), was in error probably due to gradients in the C field which were eliminated since that work was done.
[16] A. Bohr and B. Mottelson, Kgl. Danske Videnskab. Selskab Mat-fys. Medd **27**, No. 16 (1953).
[17] A. Bohr, Phys. Rev. **81**, 134 (1951).

TABLE I. Quantities pertinent to the calculation of the magnetic moment of Cs^{134m} according to the models above. The experimental moment is $+1.0964\pm0.0002$.

	(1) Single-particle model		(2) Empirical model		(3) Collective model		
	$d_{5/2}(p)$	$g_{7/2}(p)$	$d_{5/2}(p)$	$g_{7/2}(p)$	$d_{5/2}(p)$	$g_{7/2}(p)$	Reference 16
μ	2.879	−0.361	1.096	1.096	2.93	−24	−1.16
g_n	free		−4.76	−2.22	free	···	···
g_p	free		···	3.36	··	···	···

For the empirical model based on quenched spin moments we assume that the proton moment contribution to the total moment of Cs^{134m} is identical to the empirical proton moment in Cs^{131} and Cs^{133} for the configurations D and G, respectively. The spin moment of the odd $h_{11/2}^{-1}$ neutron is adjusted so that the resultant moment (assuming j-j coupling) agrees with the experimentally observed moment for Cs^{134m}. It would be interesting to combine the empirical moment for the $Z, N-1$ nucleus with that of the $Z-1, N$ nucleus in order to test the assumption of j-j coupling and the importance of interactions between nucleons of different type. Unfortunately the moment of the 11/2 state of Xe^{133} is unknown.

For the collective model we make the usual assumption that the g factors g_Ω associated with the projection Ω of j onto the nuclear symmetry axis, are equal to the Schmidt g_j factors. The angular momentum $\Omega=\Omega_n+\Omega_p$ is set equal to the observed spin $I=8$ with $\Omega_n=11/2$ and $\Omega_p=5/2$. The results of these calculations are shown in Table I along with a result of Gallagher and Moskowski[18] for the collective model using coupling rules developed by the later authors.

The "quenched" g_n for configuration D is larger than the free-neutron g value and is therefore excluded as a possibility. It is clear that with the possible exception of the empirical model based on configuration G, none of the models considered here can describe the magnetic moment of Cs^{134m}. Since the empirical model moment agrees with observation by definition, we must turn to the hyperfine structure anomaly (hfsa) for further comparison.

The value -1.39% is the largest hfsa yet reported but this fact is not too surprising when one makes an estimate of the magnitude of possible anomalies in the region of $Z=55$. According to Bohr and Weisskopf[1] the hfsa may range up to a value whose magnitude is of the order of $(ZR_0/a_0)\ (a_0/2ZR_0)^{2(1-\rho)}[(R/R_0)^2]_{\rm av}$ where a_0 is the Bohr radius, R_0 is the nuclear radius, $\rho=(1-Z^2\alpha^2)^{\frac{1}{2}}$, and α is the fine structure constant. For Cs^{134m} the above expression is between 1% and 2%. This is, however, only a crude estimate, since the hfsa will depend critically on how the total nuclear magnetism is constructed of constituent spin and orbital contributions, which must be essentially different for Cs^{133} and Cs^{134m}. The effect of smearing out the nuclear magnetism over a finite volume is to alter the hyperfine interaction from that due to a point dipole of the same magnitude located at the center of the nucleus. The negative sign for ${}_{133}\Delta_{134m}$ indicates that the actual hyperfine interaction for Cs^{133} is reduced and/or the actual interaction in Cs^{134m} is increased from the values for hypothetical point nuclear dipoles.

We have calculated the hfsa ${}_{133}\Delta_{134m}$ for two models, the single-particle model and the empirical model, with quenched spin moments used above for the magnetic moment of Cs^{134m}. The calculations are easily done by consulting Eisinger *et al.*,[19] Breslau *et al.*,[20] and Eisinger and Jaccarino.[21] The values of pertinent parameters were taken from tables and graphs of reference 21. We used the relationship $R_0=1.2\times10^{-13}A^{\frac{1}{3}}$ cm, giving the nuclear charge radius in terms of the atomic number. The fractional change in the hfs brought about by using distributed nuclear magnetism instead of a point dipole is called ϵ and ${}_{133}\Delta_{134m}=\epsilon^{133}-\epsilon^{134m}$. The values of ϵ and Δ are given in Table II.

The results presented in Tables I and II indicate that the simple models considered here are inadequate to account for either the moments of or the anomaly between Cs^{133} and Cs^{134m} with the possible exception of the empirical model based on configuration D which gives an anomaly of the correct sign and of the proper magnitude. Use of effective proton spin moments, however, has been unsuccessful for explaining anomalies between the odd-A cesium isotopes[22] $Cs^{133,135,137}$ so that if the empirical configuration D has any merit, it must be because it represents well the $h_{11/2}^{-1}$ neutron which is undoubtedly responsible for the spin 11/2 level in Xe^{133}.

Although a wave function for Cs^{134m} which consists of about a 50-50 mixture of single-particle configurations D and G gives the right moment, it produces an anomaly which is rather large. Assuming that cross terms of matrix elements are small ($\Delta l=2$), the resulting hfsa is about -3.2% when a S.P.M. is employed for Cs^{133}. Perhaps the most likely candidate at present for a successful explanation of the hfsa is the configuration-

[18] C. G. Gallagher and S. A. Moszkowski, Phys. Rev. **111**, 1282 (1958).

[19] J. T. Eisinger, B. Bederson, and B. T. Feld, Phys. Rev. **86**, 73 (1953).

[20] N. Breslau, G. Brink, and J. Khan, Phys. Rev. **123**, 1801 (1961).

[21] J. Eisinger, V. Jaccarino, Revs. Modern Phys. **30**, 528 (1958).

[22] H. H. Stroke, V. Jaccarino, D. S. Edmonds, Jr., and R. Weiss, Phys. Rev. **105**, 590 (1957).

TABLE II. Values of ϵ and Δ in percent for the pure s.p.m. (single-particle model) and for an empirical model based on quenched spin moments. No entry indicates that the quenched moments were larger than free moments and were therefore excluded from consideration.

Model	ϵ^{133}	ϵ_D^{134m}	ϵ_G^{134m}	$d_{5/2}(p)$ ${}_{133}\Delta_{134m}$	$d_{7/2}(p)$ ${}_{133}\Delta_{134m}$	Δ_{expt}
(1) S.P.M.	−0.21	−0.22	−6.22	+0.01	+6.01	−1.39
(2) Empirical quenched spins	−0.29	···	+0.53	−0.82	···	−1.39

mixing model which has been applied[23] to the anomalies of the odd-even cesium isotopes with some success. Unfortunately, the model has not been applied to odd-odd isotopes.

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